

Sen. 09/899,934



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



Publication number: **0 644 578 A2**

(12)

# EUROPEAN PATENT APPLICATION

(21) Application number: 94113803.4

(51) Int. Cl.<sup>6</sup>: H01L 21/00

(22) Date of filing: 02.09.94

(30) Priority: 16.09.93 JP 230187/93  
18.03.94 JP 48286/94

(43) Date of publication of application:  
22.03.95 Bulletin 95/12

(84) Designated Contracting States:  
DE GB IT

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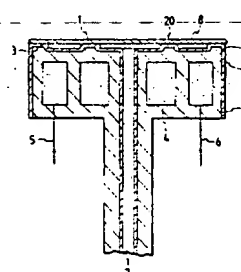
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(54) Method of holding substrate and substrate holding system.

(57) Present invention provides a method of holding substrate and a substrate holding system where the amount of foreign substances on the back surface can be decreased, and a little amount of foreign substances may be transferred from a mounting table to a substrate. The substrate holding system comprises a ring-shaped leakage-proof surface having smooth surface on the specimen table corresponding to the periphery of the substrate, a plurality of contact holding portions against the substrate on the specimen table between the corresponding position to the periphery of the substrate and the corresponding position to the center of the substrate, and electrostatic traction means for fixing the substrate by contacting the back surface of the substrate to the ring-shaped leakage-proof surface and the contact holding portions. The substrate contacts to the cooling surface at the ring-shaped leakage-

proof surface and the contact holding portion placed on a position inside the ring-shaped leakage-proof surface. The back surface of the substrate and the cooling surface do not contact to each other in the large portion of the remaining area.

FIG. 2



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## Background of the Invention

### Field of the Invention

The present invention relates to a method of holding a substrate and a substrate holding system to hold a substrate certainly in a production process for treating the substrate such as semiconductor device while it is being cooled.

### Description of the Related Art

Among substrate treating apparatuses of a production process for semiconductor devices, there are a lot of substrate treating apparatuses requiring to cool substrates, such as a plasma treatment apparatus, a sputtering apparatus, a dry etching apparatus, a CVD (chemical vapor deposition) apparatus and a high energy ion implantation apparatus. Since the treating environment in these apparatuses is generally vacuum, it is difficult to cool a substrate by contacting it to a cooling surface as in the atmospheric pressure because of decrease in thermal conductivity. Although there is abundant literature for thermal conductivity in vacuum (rarefied gas), the amount of heat transferred by contact is small because of small real contact area when common contact surfaces come into contact with each other. Especially in heat transfer between a substrate and a cooling surface, it is difficult that the substrate is strongly pressed to the cooling surface since there is possibility to caused the damage of substrate. Therefore, various ideas such as placing soft elastomer on the surface contacting to a substrate have been proposed. However, in recent years, it becomes ordinary that a gas is introduced between a substrate and a cooling surface to cool the substrate using the gas as a coolant, since heat load in the substrate increases or requirement to cool the substrate to lower temperature arises.

There are various types of gas cooled substrate holding systems. They can be roughly categorized into the followings: (1) a gas cooling type where the back surface of a substrate and a cooling surface contact to each other and a gas is introduced into the gap between the both surfaces formed by the surface roughness, and (2) a gas cooling type where the back surface of a substrate and a cooling surface do not contact to each other and a gas is introduced into the gap between the both surfaces in the same way as above.

The prior art of gas cooling type belonging to the former are described in, for example, Japanese Patent Publication No.2-27778 (1990), Japanese Patent Application Laid-Open No.62-274625 (1987), Japanese Patent Application Laid-Open No.1-251375 (1989), Japanese Patent Application Laid-

Open No.3-154334 (1991) and Japanese Utility Model Application Laid-Open No.4-8439 (1992). And the prior art of gas cooling type belonging to the latter are described in, for example, Japanese Patent Application Laid-Open No.63-102319 (1988), Japanese Patent Application Laid-Open No.2-312223 (1990), Japanese Patent Application Laid-Open No.3-174719 (1991). Further, there is another type, described in Japanese Patent Application Laid-Open No.2-30128 (1990), where before introducing a cooling gas the back surface of a substrate and a cooling surface contact to each other, but during cooling the substrate is pushed up due to gas pressure caused by introducing a cooling gas and does not contact to the cooling surface.

In these cooling, providing that a certain cooling gas is used, the cooling capacity (magnitude of transferred heat) with the cooling gas depends on the pressure of the gas and the distance between the back surface of a substrate and a cooling surface (gap in the back surface of the substrate). FIG.8 schematically shows the characteristic of thermal conductivity in low pressure. When the pressure of the cooling gas is low, the amount of transferred heat is proportional to the pressure of cooling gas and independent of the magnitude of the gap between both of the surface. When the pressure of the cooling gas is higher than the pressure  $P_0$  where the mean free path of the cooling gas nearly agrees to the gap, the amount of transferred heat becomes constant and independent of the gas pressure. The pressure of the cooling gas in the type (1) described above is generally in the region where the heat transfer is proportional to pressure, and the pressure of the cooling gas in the type (2) described above is generally in the region where the heat transfer is independent of pressure.

Characteristics and problems in various cooling methods of substrate will be described below.

First, description will be made on the case where cooling is performed under a condition that a substrate contacts to a cooling surface. The cooling methods belonging to this type are Japanese Patent Publication No.2-27778 (1990), Japanese Patent Application Laid-Open No.62-274625 (1987), Japanese Patent Application Laid-Open No.1-251375 (1989), Japanese Patent Application Laid-Open No.3-154334 (1991) and Japanese Utility Model Application Laid-Open No.4-8439 (1992). In the cooling method of this type, although the substrate and the cooling surface contact to each other, only the most protruded portions on the cooling surface contact with the substrate when it is observed in detail. The indented portions on the cooling surface and on the substrate do not contact to each other, and the gaps are approximately 10 $\mu$ m to 50 $\mu$ m although it depends on the surface

roughness. In a case where a cooling gas is introduced in the gap, the pressure is generally several Torr which is in a region nearly equal to the mean free path. Therefore, a sufficient cooling efficient can be obtained by properly setting the pressure as shown in FIG.8.

However, when the cooling gas is supplied from a specified single portion as shown in the figure in Japanese Patent Publication No.2-27778 (1990), the pressure is highest in the cooling gas supplying portion and decreases as it goes toward the peripheral portion of the substrate. Since the cooling efficiency has pressure dependence as shown in FIG.8, there arises a disadvantage that uniformity of the temperature distribution is deteriorated due to non-uniformity of the cooling efficiency. If there is no gas leakage, that is, no gas flow, the pressure distribution does not occur and the temperature distribution becomes uniform. However, in order to achieve this, the peripheral portion of the substrate needs to be shielded. This example is described in Japanese Patent Application Laid-Open No.62-274625 (1987) or in Japanese Utility Model Application Laid-Open No.2-135140. Further, the method in which cooling gas is supplied from plural portions to make the pressure distribution on the back of the substrate uniform is described in Japanese Patent Application Laid-Open No.1-251735 (1989) or in Japanese Patent Application Laid-open No.4-61325 (1992). In any case, in these cooling methods, since the back surface of the substrate and the cooling surface contact to each other in a large area, there is a disadvantage that there are a lot of foreign substances on the back surface of the substrate attached by contacting to the cooling surface. Further, in order to prevent the cooling gas from leakage through the peripheral portion of the substrate using a shielding material, the load for the shielding needs to be applied. Therefore, means tightly fixing the substrate with some manner is required.

Description will be made below on the cooling method where a substrate and a cooling surface do not contact to each other from beginning and a cooling gas is supplied into the gap. The prior art of this method is described in Japanese Patent Application Laid-Open No.3-174719 (1991) or in Japanese Patent Application Laid-Open No.4-6270 (1992), in which a substrate is mechanically fixed to a cooling surface from the top surface or the side surface of the substrate. Since the substrate, in these examples, is mechanically fixed, there is a disadvantage that foreign substances are apt to be produced at the fixing portion. In the methods described in Japanese Patent Application Laid-Open No.63-102319 (1958) and in Japanese Patent Application Laid-Open No.2-30128 (1990), a sub-

strate is not fixed specially, but is held by the weight of substrate itself. In this case, in order that the leakage of the cooling gas is not increased so much or the substrate is not floated up, the pressure of the cooling gas has to be limited low. This causes a disadvantage that the cooling efficiency is decreased.

Electrostatic adhesion is known as a method of fixing a substrate electrically. An example where a substrate is fixed to a cooling surface with this method and projections are provided on the periphery of the substrate is described in Japanese Patent Application Laid-Open No.62-208647 (1987). A substrate contacts to a cooling surface only a plurality of projections provided in separate spaced relation on the outer periphery and inner periphery of the substrate, which is described as a prior art in the Japanese Patent Application Laid-Open No.62-208647 (1987). And this example is described that cooling gas easily leaks and adhering force is unstable. Further, in order to improve this method, it is effective that the outer periphery is not projected and the projections are provided only on the inner peripheral portions, and further the projections in the inner periphery are provided in the central portion instead of separate spaced relation. In this case, the gap between the substrate and the cooling surface becomes non-uniform over the surface of the substrate, which causes non-uniform pressure distribution on the back surface of the substrate. When the gap between the back surface of the substrate and the cooling surface is different by position, the ratio of the mean free path of the cooling gas and the gap has a distribution over the surface of the substrate. Therefore, it arises a disadvantage that the temperature distribution is apt to become large due to the difference in cooling efficiency as can be understood from FIG.8 even if the pressure distribution is not so large. In the electrostatic adhering method described in this example, there are provided a positive and a negative electrodes on the cooling portion to which a direct

current high voltage is applied to produce electrostatic adhering force. In the electrostatic adhering method of this type, there may arise a disadvantage in that when a substrate is treated in a plasma, electric charge on the surface of substrate by irradiated ions or electrons is apt to be non-uniform, current flowing on the surface of substrate to damage the substrate.

Each of the conventional technologies, as described above, aims mainly to cool a substrate efficiently. However, as increasing in integration of semiconductor device in recent years, it is required to decrease the amount of small foreign substances such as particles or dusts and heavy metal impurities less than the allowable limit in the past. The same can be said on the foreign substances

attached on the back surface of a substrate. When the amount of foreign substances attached on the back surface of a substrate is large, there arises a disadvantage in the next process that the foreign substances on the back surface are attached to the top surface of an adjacent substrate, or are removed once from the substrate and attached to another substrate. Therefore, decreasing the amount of foreign substances is an important problem for stabilizing the semiconductor production process or improving the yield. Attaching foreign substances on the back surface of a substrate occurs by contacting the back surface of the substrate to another member. Therefore, a lot of foreign substances are attached to a substrate by contacting to a cooling surface for the substrate.

Further, the prior art does not refer to the consideration against substrate size. Although it is mentioned that the influence upon the process is lessened by leaking cooling gas into the treating chamber with adhering force as small as possible, the relation between the adhering force and the cooling gas pressure is not mentioned.

A conventional substrate holding system in a substrate etching apparatus generally employs a method in which a substrate is pressed its periphery with hooks to hold' as described in Japanese Patent Application Laid-Open No.2-148837 (1990) or Japanese Patent Application Laid-Open No.2-267271 (1990). When there is such a member contacting to the surface of the substrate, problems arise in that the contact portions in the substrate are obstructed to be etched, the contacting member itself being also etched in some kind together with the substrate. As the results, the foreign substance sources such as reaction products are attached to the contacting member and the contacting member being damaged, which may lead to producing foreign substances.

On the other hand, in a substrate holding method in which a substrate is held using electrostatic force (hereinafter, referred to as "electrostatic adhering"), as described in, for example, Japanese Patent Application Laid-Open No.2-135753 (1990), a substrate is placed on an electrostatic adhering portion made of a dielectric material and a high voltage is applied to them to hold the substrate with electrostatic adhering force. In this case, there is no special member to press the substrate in the periphery of the substrate. Therefore, the problem of the possibility of producing the foreign substances as described in the above example is solved. However, the positional relationship between the substrate and the electrostatic adhering member is that the substrate is placed in the uppermost (substrate etching space side) and a step is formed in the electrostatic member such that the electrostatic adhering member comes to

be placed below the substrate. When such a step exists, gas flow during etching a substrate changes abruptly at the periphery of the substrate to cause a non-uniform etching in the substrate in some cases.

#### Summary of the Invention

An object of the present invention is to provide a method of holding substrate and a substrate holding system where amount of foreign substances on the back surface can be decreased, and a little amount of foreign substances may be transferred from a mounting table to a substrate.

Another object of the present invention is to provide a method of holding substrate and a substrate holding system where the deformation in a large diameter substrate can be suppressed, and the cooling efficiency for the substrate can be kept in sufficiently high.

A further object of the present invention is to provide a method of holding substrate and a substrate holding system where the damage of a substrate caused during treating the substrate can be prevented.

A still further object of the present invention is to provide a method of holding substrate and a substrate holding system where a cooling gas can be speedily filled over the back surface of a substrate when the cooling gas is introduced after the substrate is electrostatically attracted, and substrate temperature control suitable for high productivity can be performed.

Another object of the present invention is to improve the product yield of substrate etching and the availability of the substrate etching apparatus by means of providing the substrate holding system decreased in foreign substances as described above and being capable of performing uniform etching.

According to the present invention, it is provided a ring-shaped leakage-proof surface having smooth surface on the specimen table corresponding to the periphery of the substrate, a plurality of contact holding portions against the substrate on the specimen table between the corresponding position to the periphery of the substrate and the corresponding position to the center of the substrate, and electrostatic attraction means for generating an electrostatic attraction force to attract the substrate toward the ring-shaped leakage-proof surface and the contact holding portions.

In order to decrease the foreign substance which may be adhered on a substrate, it is effective to decrease the contact area between a cooling surface and a substrate. However, the distance between the cooling surface and the back surface of the substrate needs to be kept in a distance so

as not to decrease the cooling efficiency through a cooling gas. In order to realize this, a small high step is provided on the cooling surface such that the back surface of the substrate and the cooling surface do not contact to each other even if whether the cooling gas is introduced or not. Although the cooling surface and the back surface of the substrate contact to each other at protruded portions provided on the step portion of the cooling surface, the area of the contact portions needs to be limited to as small as necessary. In the present invention, therefore, an electrostatic attraction function is given to the cooling surface to attract the substrate to the protruded portions of the cooling surface.

Prevention of leakage of the cooling gas has to be considered. According to the present invention, this can be attained by providing a ring-shaped protruded portion having smooth surface, that is, leakage-proof surface, on the cooling surface corresponding to the peripheral portion of a substrate, fixing the back surface of the substrate to the cooling surface with electrostatic adhesion to prevent the cooling gas from leaking.

According to the present invention, the following effects are obtained. One of the effects is a solution for the problem on the transportation of foreign substances in a pusher portion relating to handling of substrate. The pusher provided inside or through a mounting table contacts to other members and cannot avoid from a foreign substance source. In the present invention, the excess cooling gas flows toward the opposite side of the mounting table through the hole. Since the foreign substances produced are carried in the opposite direction to the substrate, the amount of foreign substances attached to the substrate is decreased.

Another effect of the present invention is that a cover is provided in the back surface of the mounting table to protect the mechanism in the back surface of the mounting table from attaching of reaction products for a long time as far as possible. Since complex mechanisms such as coolant supplying system and vertical driving mechanism for mounting table are usually constructed in the back of the mounting table, it is troublesome in handling when the reaction products produced by etching attach to these parts. In order to avoid this, according to the present invention, a cover is provided in the back surface of the mounting table such that the excess gas of cooling gas flows into the inside of the cover, the pressure inside the cover being kept higher than the pressure in the treatment chamber during treating to suppress the reaction products to enter the treatment chamber, which protects the mechanism in the back surface of the mounting table from attaching of reaction products for a long time as far as possible.

The prevention of damage in substrate can be attained by connecting the electric circuit for electrostatic adhesion from the substrate side to an earth part such as the vacuum chamber through the plasma to minimize the electric potential over the surface of substrate.

According to the present invention, a substrate contacts to a cooling surface at a ring-shaped leakage-proof surface and at contact holding portions positioning in the inner side of the ring-shaped leakage-proof surface. However, since the back surface of the substrate does not contact to the cooling surface in the most remaining part of the area, attaching of foreign substances caused by contact can be prevented. Although the cooling efficiency for the substrate cooling is decreased a little comparing to when the substrate contacts to the cooling surface under the same pressure of the cooling gas, a sufficient cooling efficiency can be obtained by forming the step on the cooling surface smaller than approximately 100 times of the mean free path of the cooling gas. The gap between the back surface of the substrate and the cooling surface is large comparing to that in the conventional cooling method where the substrate and cooling surface contact to each other over the whole surface. Therefore, the conductance between the both surfaces is large so that supplying and exhausting of cooling gas are easily performed. That is, the time to supply and exhaust the cooling gas is short, and then the time for treating a substrate can be shortened. Further, there is a function that the conductance at contact portion of the periphery of the substrate and the cooling surface is very small comparing to the non-contact portion of the inner portion of the substrate (in the molecular flow region, the conductance is proportional to the square of gap), the pressure difference across the non-contact portion being small, that is, the cooling efficiency being uniform.

When a substrate temperature is controlled using a cooling gas as a coolant, the pressure of the cooling gas is required to be higher than 2 Torr. And the higher the pressure is, the higher the efficiency of heat transfer becomes. On the other hand, the electrostatic adhering force largely depends on the temperature of the substrate to be controlled. In a process of production line today, the temperature is approximately  $-60^{\circ}\text{C}$  to  $+100^{\circ}\text{C}$ , the adhering force of 40 to 100 gf/cm<sup>2</sup> being stably obtained under applied voltage in general of 300 to 1000V. Concerning the pressure control of cooling gas, it is difficult to control the pressure precisely, since the pressure largely changes depending on the time constant of the gas supplying system or the relationship between the relative roughnesses of contact surfaces of the substrate and the mounting table. Therefore, the

target of the pressure control may be, for example, 10Torr  $\pm$  5Torr.

When the outer periphery of the substrate is fixed by adhesion with the conventional method and a gas is filled in the back of the surface with the pressure of 10 Torr, the substrate is deformed by 0.1 to 0.25mm. This magnitude of deformation degrades the work accuracy of substrate etching as well as lessens the heat transfer efficiency by cooling gas. To solve this problem, adhering portions are additionally provided on the center side of a substrate, for example, one ring-shaped adhering portion for 6" substrate, two ring-shaped adhering portions for 8" substrate, in addition to the adhering portion on the periphery of the substrate. Therewith, the deformation can be prevented.

It is well known that when a substrate contacts to another member, foreign substances are certainly attached to the contact point. From this point of view, it is clearly preferable that the electrostatic adhering surface is small. However, taking pressure control level and adhering force into consideration as described above, it is suitable in the up-to-date technical level that the adhering area is less than approximately half of the total area of the substrate. This is because that when electrostatic adhering force is 40 gf/cm<sup>2</sup> and adhering area is half of the total area, the total adhering force for 8" substrate becomes approximately 6280 gf, and the separating force with the cooling gas of 15 Torr is approximately 6100 gf.

Further, by providing a pusher for serving substrate transportation in a hole penetrating to the back surface of the mounting table, the excess cooling gas serves as a carrier gas for carrying foreign substances produced at the pusher portion to prevent the foreign substances from attaching to the substrate. In addition to this, the excess cooling gas is introduced into the inside of a cover on the back surface of the mounting table and makes the pressure inside the cover higher than the pressure in the treating chamber to prevent contamination of and attaching of reaction products to the mechanisms on the back of the mounting table.

In order to prevent abnormal discharge from occurrence when the high frequency voltage is applied to the substrate to generate bias voltage for etching the substrate, a high frequency voltage applying portion and a standard electric potential portion are insulated with an electrically insulating material not so as to facing to each other directly. In addition to the above measures, a pin for transporting the substrate is provided and is constructed such as to be electrically conductive. Since the electrostatic adhering force due to remaining charge can be instantaneously disappeared by removing the charge accumulated in the substrate by means of contacting the pin to the substrate when

the substrate is transported, the substrate is not lifted with unnecessary force.

Since the flow passage to conduct the coolant for controlling the temperature of the substrate is formed with diffusion welding or soldering in such a structure that the portion forming the flow passage is completely jointed, no seal is required when a through hole is provided in any place except the flow passage. Therefore, a temperature detector or a detector for detecting the presence or absence of substrate.

In order to make the gas flow on the surface of a substrate uniform, a gas flow uniforming member (hereinafter referred to as "susceptor") is provided in the outer peripheral portion of the substrate. The surface of the susceptor is in a higher level than that of the substrate so that the gas flow does not abruptly change at the periphery of the substrate. The surface of the susceptor facing to the periphery of the substrate is formed in normal to the surface of the substrate to restrict the movement in the lateral direction or sliding of the substrate. Further, there are some cases in which the reaction products produced by substrate etching or the plasma turns in the gap between the cover member facing to the back surface of the substrate in the peripheral portion and the back surface of the substrate to attach foreign substances on the back surface of the substrate. This phenomena is prevented by means of making the distance between the back surface of the substrate and the cover member.

As described above, since the foreign substance source attached to a substrate is eliminated as far as possible, the foreign substances can be decreased. Further, since the gas flow is uniformed, the uniformity in the substrate etching over the surface can be improved. Since the detector for measuring substrate temperature and the detector for detecting the presence or absence of substrate can be easily installed by means of modification of the structure and the manufacturing method of the substrate holding system, the reliability and the operability of the apparatus can be improved.

#### Brief Description of the Drawings

FIG.1 is a vertical cross-sectional view showing an outline of a substrate treatment apparatus to which a substrate holding system in accordance with the present invention is applied.

FIG.2 is a vertical cross-sectional view showing an embodiment of the substrate holding system in FIG.1.

FIG.3 is a vertical cross-sectional view showing another embodiment of the substrate holding system in FIG.1.

FIG.4 is a top plan view showing the substrate holding system in FIG.3.

FIG.5 is a top plan view showing another embodiment of a substrate holding system.

FIG.6 is a top plan view showing a further embodiment of a substrate holding system.

FIG.7 is a vertical cross-sectional view showing another embodiment of a substrate holding system in accordance with the present invention.

FIG.8 is a view explaining the heat transfer characteristic in vacuum.

FIG.9 is an explanatory view showing another embodiment of a substrate holding system in accordance with the present invention.

FIG.10 is an explanatory view showing a substrate etching apparatus having a substrate holding system in accordance with the present invention.

FIG.11 is an enlarged view showing the outer peripheral portion of the substrate holding system.

FIG.12 is an explanatory view showing removing accumulated charge during transporting a substrate.

FIG.13 is a vertical cross-sectional view showing another embodiment of a substrate holding system in accordance with the present invention.

FIG.14 is an explanatory view showing an embodiment of a method of manufacturing the coolant flow passage in the substrate holding system.

FIG.15 is an explanatory view of another embodiment of a substrate holding system.

FIG.16 is an explanatory view of the coolant flow passage of a holding member in Fig. 15.

#### Detailed Description of the Preferred Embodiments

As a first embodiment according to the present invention, FIG.1 shows an embodiment employing an electrostatic adhering circuit for fixing a substrate 1 to a holding member 2. In FIG.1, a microwave plasma etching apparatus is used for treating the substrate 1. A substrate holding system 9 mounting the substrate 1 is placed in an etching chamber 10. The etching chamber 10 is exhausted with a vacuum pump 11; a gas for etching being supplied from a gas supply unit. The substrate holding system 9 is connected to a high frequency power source 12 and a direct current power source 13. Microwave is introduced into the etching chamber 10 from a quartz glass window 15 through a wave guide tube 14. When the high frequency power source 12 is come into operation or the microwave is introduced, plasma 16 is produced in the etching chamber 10. At that time, an electrostatic adhering circuit 17 is formed by the potential of the direct current power source 13 through the substrate holding system 9, the substrate 1, the plasma 16. In this state, the substrate 1 is fixed to the substrate holding system 9, that is, fixed by the

electrostatic force produced in the substrate holding system 9.

FIG.2 shows the cross-section of the substrate holding system 9 in FIG.1. A substrate 1 is mounted on a protruded portions 3 and 20 of a holding member 2 for substrate, the protruded portion 3 of the holding member 2 being connected to an electrostatic adhering circuit 17, the substrate 1 being fixed to the holding member 2 at the protruded portions 3 and 20. A flow passage for flowing a coolant 4 is provided in the holding member 2 to cool the substrate 1. The coolant is supplied from a supplying unit 5 schematically illustrated and flowed out from an outlet portion 6 to control the temperature of the holding member 2. Further, a flow passage for a cooling gas 7 is provided in the center of the holding member 2 to supply and exhaust the cooling gas 7. The temperature control of the substrate 1 is attained by the cooling gas 7 filled in the indented portion 8 of the holding member 2 preforming heat transfer between the holding member 2 and the substrate 1. The electrostatic adhering force is generated by a dielectric material 18 attached or formed on the surface of the holding member 2.

Aluminum oxide or mixture of aluminum oxide added titanium oxide may be used as the dielectric material 18. The voltage of several hundred volt is applied to the holding member as the direct current voltage for generating the electrostatic force. Therewith, the substrate is electrostatically fixed to the protruded portion 3 of the holding member 2 shown in FIG.2. The electric potential for electrostatic adhering is applied from the direct current power source 13, the potential being uniform over the holding member 2, over the protruded portion 3 and over the outer periphery of the substrate 1. Therefore, the potential difference produced over the surface of the substrate 1 is caused by the distribution of electrons or ions irradiated on the substrate 1, and is not so high that the potential difference may give a damage to the substrate 1. On the other hand, in a method where positive and negative electric poles are formed in the holding member 2 to adhere the substrate electrostatically with the electric poles, there is a possibility that a high voltage difference in the substrate 1 to give a damage to the substrate.

Then the cooling gas 7 is supplied to the back surface of the substrate 1 fixed such a manner. The cooling gas 7 is filled in the indented portion 8 of the holding member 2, the pressure being within the range of several Torrs to several ten Torrs. When the gap of the indented portion 8 is 15 $\mu$ m to 0.1 or 0.2mm, decrease of the cooling efficiency can be neglected. That is, the gap needs to be larger than 15 $\mu$ m when the existence of particles or the roughness of surface is considered, and the



upper limit of the gap is 0.2mm when the thermal conductance of gas is considered.

It can be considered that the electrostatic adhering force is nearly zero over the indented portion 8 where there is the gap, and is generated only over the protruded portion 3. However, since it is possible to set the adhering force strong enough to endure the pressure of the cooling gas 7 by properly setting the voltage of the direct current power source 13, the substrate 1 is not moved or separated by the cooling gas 7.

The temperature of the holding member 2 is controlled with cooling by the coolant 4. Therefore, the molecule of the cooling gas 7 cooled on the surface of the indented portion 3 of the holding member reaches the substrate 1 directly or after any number of collisions with other molecules of the cooling gas. The molecule of the cooling gas reached the substrate 1 receives energy from the substrate 1, that is, cools the substrate 1, returning again to the holding member. By repeating the cycle above, the substrate 1 is cooled. In the case where the pressure of the cooling gas 7 is sufficiently higher than the pressure having the mean free path corresponding to the gap at the indented portion 3, it becomes a dominant phenomenon that the gas molecules collide to and exchange energy with each other to carry the thermal energy in the substrate 1 to the cooling surface of the holding member 2 in addition to the above phenomenon of gas molecules. However, the thermal energy transport within the range of the present invention is heat conduction through the cooling gas 7 as a thermal medium. In other words, it is not the phenomenon where, for example, the cooling gas 7 is cooled with a cooling unit separately provided in advance and conveyed to the back surface of the substrate 1 to cool the substrate with the heat capacity of the gas. The gap of the intended portion 3 and the pressure of the cooling gas 7 satisfying the above condition are chosen.

The ratio of energy transport between the cooling gas 7 and the holding member 3 is expressed by a value called thermal adaptation factor. The thermal adaptation factor depends on the kind of cooling gas and the surface condition of member (state of contamination etc.). The same can be applied to the heat transfer between the substrate 1 and the cooling gas 7. Helium is used as the cooling gas 7 because helium does not affect etching characteristic when it leaks, and because the supplying or exhausting time for the cooling gas 7 is shorter than the other gases. However, other gases such as nitrogen, argon, an etching gas may be used although the cooling efficiency is changed. The cooling gas is not specially limited to these.

As described above, the substrate 1 is sufficiently cooled through the cooling gas. Further the

substrate contacts to the holding member 2 only at the protruded portion 3. The portions having possibility to be attached foreign substances produced by contacting the back surface of the substrate to other member are only the portions on the back surface of the substrate corresponding to the protruded portion 3. In a case where the substrate 1 has a larger area than the holding member 2 and a part of the surface of the holding member sticks out of the substrate 1 shown in FIG. 2, plasma is irradiated on the sticking surface to etch and the etching reaction products from the substrate 1 are attached to the sticking surface. Thereby, the foreign substances attaches to the top side surface of the substrate 1 through the sticking surface.

This is the reason why the diameter of the holding member 2 is smaller than the diameter of the substrate 1. However, the effect of decreasing foreign substances on the back surface according to the present invention is not degraded even when the diameter of the holding member 2 is larger than the diameter of the substrate 1.

FIG.3 shows an other embodiment according to the present invention. Although the embodiment in FIG.3 is basically the same as that in FIG.2, the embodiment in FIG.3 has a pusher 19 for transferring the substrate 1. The substrate 1 is transferred from the holding member 2 by moving the pusher 19 upward and downward. The pusher 19 has to be moved upward and downward every treatment. That is, the pusher needs to be moved independently of the holding member 2. Therefore, there is a need to provide a gap between the holding member 2 and the pusher 19. The cooling gas 7 leaks through the gap. The leakage amount of cooling gas 7 needs to be suppressed as low as possible. In order to realize this, an inner side protruded portion 20 having a surface nearly the same height or the same height as that of the protruded portion 3 is provided around the pusher 19. Since the surface is flat and contacts to the substrate 1, the leakage amount of the cooling gas can be suppressed within an allowable amount. The reasons why the pusher is provided in the center of the protruded portion 20 are the following three.

- (1) To exhausting the excess gas,
- (2) To exhausting the foreign substances produced at the pusher portion with the gas flow,
- (3) To prevent an abnormal discharge.

The occurrence of abnormal discharge depends on the kind of gases, the pressure of environment, the gap distance applying voltage and the voltage. In a case where the pusher is placed, for example, in a cooling gas environment, the gap distance applying voltage needs to be 0.16 to 0.2 mm when the pressure of the cooling gas environment is 8 to 10 Torrs (mHg) and the voltage for



electrostatic adhering is 450 to 700 V. However, forming such a gap is a difficult work. In the case of the embodiment according to the present invention, the pressure of the environment containing the pusher 19 can be made extremely lower than the pressure easy to occur discharge and the abnormal discharge can be prevented from occurring even when the pressure of the environment containing the pusher 19 is higher than the pressure in the etching chamber of 3 to 5 mmTorr by the pressure difference for increasing conductance, for example, 10 mmTorr ( $1/10^2$  mmHg) and the gap distance is approximately 1 mm.

FIG.4 is a view of the substrate holding system 9 in FIG.3 removing the substrate 1 looking down from upper side. A feeding and exhausting hole 21 for the cooling gas 7 is provided in the center of the holding member 2 and, the pushers 19 and the inner side protruded portions 20 are arranged around the feeding and exhausting hole. The inner side protruded portions 20 also serves as supports against the bending of the substrate 1.

Although the inner side protruded portion 20 is round-shaped in FIG.4, the shape is not limited to round-shape. Fig. 5 shows an embodiment of a substrate holding system 9 being ring-shaped. There are provided in the ring-shaped protruded portions 22 a temperature sensor 23 for the substrate 1, a substrate detecting sensor 24 for detecting existence of the substrate, an earth terminal 25 for bringing the potential of the substrate 1 to earth potential in addition to the pusher 19. In order to perform speedy feeding and exhausting of the cooling gas 7 to the indented portion 8, parts of the ring-shaped protruded portion 22 are cut to make the cooling gas 7 pass through the parts easily.

In an apparatus using plasma, employing a fluorescent thermometer as the temperature sensor 23 eliminates the problem of noise. An example of the substrate detecting sensor 24 is an optical fiber through which laser beam is introduced to irradiate the back surface of the substrate 1. Existence of the substrate 1 is detected by existence of reflected light. Since the output of the temperature sensor 23 changes depending on existence of the substrate 1, the change can be used in detecting existence of the substrate 1.

The earth terminal is used before pushing up the substrate 1 electrostatically-fixed by using the pusher 19. While remaining adhering force is existed in the substrate 1 electrostatically fixed, the pusher 19 cannot be used. Therefore, in order to shorten the waiting time, there are some cases where the substrate 1 is required to be grounded. By moving the earth terminal 25 upward and downward to be contacted to the substrate 1, potential of the substrate 1 is grounded. Although the earth terminal 25 is made of an electric conductive ma-

terial, it is effective to employ silicon carbide having a much larger resistivity than general metals to avoid an abnormal discharge during plasma treatment. Further, it is possible that the function is given to the pusher 19 such as to also serve as the function.

Although various kinds of the sensors are arranged on a single holding member in FIG.5, the sensors can be used separately without degrading the object of the present invention.

By employing the substrate holding system 9 according to the present invention, the amount of foreign substances attaching to the back surface of the substrate 1 is decreased. Further, by using the substrate 1 treated with the substrate holding system, it can be prevented to attach the foreign substances on the back surface to the top surface of another adjacent substrate, to contaminate the substrate by foreign substances melted or detached from the back surface. Susceptor 68 serving as a cover of a head portion 61 to protect the head portion 61 to be etched and to insulate the side surface of the head portion from the surrounding electrical space.

FIG.6 shows a further embodiment of a substrate holding system 9 according to the present invention. The holding member 2 has island-shaped protruded portions 22A, 22B arraying concentrically. In this embodiment, a substrate is supported with concentrically three portions, the protruded portion 3 in the peripheral portion, the island-shaped protruded portions 22A and 22B. This configuration is especially effective when the diameter of the substrate 1 is large.

FIG.7 shows another embodiment according to the present invention. FIG.7 is a cross-sectional view of a substrate holding system 9. An insulating film for electrostatic adhering is coated on the top surface of a head portion 61, a weir 62a for contacting and fixing a substrate 1 being provided on the periphery of the substrate, a weir 62b and a weir 62c being provided on the inner side of the weir 62a, a hole 66 penetrating to the back surface of a mounting table being provided in the center of the weir 62c. A space 64 for containing coolant is provided inside the head portion 61, a passage capable of feeding and exhausting the coolant being provided. A shaft 63 secured to the head portion 61 is provided near the center of the substrate holding system 9, a guiding passage for introducing cooling gas being provided inside the shaft. A pusher mechanism 65 for transporting a substrate is provided in engaging with the hole 66 described above. A cover 67 is placed in the outer peripheral portion of the penetrating hole 66 on the back of the mounting table.

In a case where a substrate 1 (wafer) is treated in the embodiment in FIG.7, the substrate 1 is

introduced into a treating chamber using loading means (not shown) under a vacuum condition, the substrate 1 being mounted on a mounting table 9 controlled its temperature in advance with a coolant, current being supplied to an electromagnetic coil 4 to form a given magnetic field, a treating gas being introduced, current being supplied to a magnetron to generate microwave, the gas being turned into a plasma in the treating chamber by ECR (electron cyclotron resonance), a DC circuit being formed by the plasma to produce an electrostatic adhering force. Then a cooling gas is filled between the substrate 1 and the mounting table 9. The cooling gas rapidly diffuses inside the gap except contact portions attracted, transferring the heat entering from the plasma into the substrate 1 (wafer) to a head portion to transfer the heat to the coolant. In order to extend the cooling effect up to the vicinity of the outer periphery of substrate, the cooling gas is leaked to the treating chamber through the outer periphery of substrate. At the same time, the cooling gas is exhausted to the back of the mounting table as an excess gas through a penetrating hole 66 having a dimensional relationship such as to leak the cooling gas actively. Since the gas between the substrate and the mounting table needs to be kept in above a given pressure, gas is always supplied by the amount corresponding to the leaked amount.

According to the embodiment, it is possible to provide a plasma treating apparatus in which the amount of foreign substances transferred to the back surface of a substrate is decreased by decreasing the contact area with keeping the cooling gas pressure required for cooling, and which having a good repeatability as a production apparatus, being capable of treating with plasma under condition of controlling the substrate temperature, and having excellent productivity.

Further, it is possible to provide a plasma treating apparatus in which the foreign substances produced in the pusher portion are transported to the opposite side of the substrate by exhausting the excess cooling gas to the back of the mounting table (opposite side of the substrate) to decrease the amount of foreign substances attaching to the substrate, concurrently the gas being exhausted inside a cover provided on the back of the mounting table in the treating chamber to keep the pressure inside the cover higher than the pressure in the treating chamber and to prevent the reaction products from attaching to the mechanisms of the mounting table, and of which the characteristic is small time-varying.

Helium is generally used as the cooling gas here. Although in the present invention the cooling gas leaks into the treating chamber by several ccm (cubic centimeter per minute) to 10 ccm, it has

been confirmed by an experiment that the leakage amount does not affect the process since the amount is 1/100 to 1/several tenth of the supplied amount of process gas.

Although the present invention has been described in each of the above embodiments with taking substrate cooling into consideration, it is understood that there is no substantial difference in a case of heating a substrate since the only difference is that the temperature of the holding member is kept higher than the temperature of the substrate.

According to the present invention, a substrate can be certainly cooled and at the same time the amount of foreign substances attached to the back surface of the substrate can be decreased. Further, the amount of foreign substances attached to the top surface of the substrate can be also decreased since the substrate is fixed with electrostatic adhesion and there is no need to use any substrate fixing hardware such as to contact to the substrate on the top surface of the substrate. Furthermore, substrate treatment on the top surface of a substrate can be performed throughout the surface of the substrate since there is no obstacle such as substrate fixing hardware. Therewith, the yield of production in substrate treatment can be improved by decreasing the amount of the foreign substances on the back surface. The yield of production can be further improved and the number of device chips obtained from a single substrate can be also increased by decreasing the amount of foreign substances attached to the top surface of the substrate.

The damage of substrate due to conventional electrostatic adhering electrode is not caused in the present invention, which improves the yield of production.

Another embodiment of the present invention will be described in detail below, referring to the drawings.

FIG.9 shows another embodiment in accordance with the present invention. In FIG.9, a substrate 1 is held on a dielectric material 18 formed on a holding member 2. Under the holding member 2, an insulating member 40 and a base 41 are placed and supported with a shaft 63. In the holding member 2, a coolant flow passage 42 for conducting a coolant to control the temperature of the substrate 1 is formed. In order to supply the coolant to the coolant flow passage 42, a through hole penetrating through the base 41 and the insulating member 40 is provided and a coolant supply portion 43 is also provided. A pusher 19 is inserted in a through hole penetrating through the holding member 2, the insulating member 40 and the base 41, the side surface of the through hole being formed of an insulating pipe 44. The pusher 19 is

guided with a guide 45 provided around the shaft 63, being moved in the direction of the shaft of the shaft 63 with an upward and downward drive mechanism, which is not shown in the figure, to transport the substrate 1. A high frequency supplying shaft 47 is installed inside the shaft 63 through an insulating material 46, the high frequency supplying shaft 47 being pipe-shaped, the inside of the high frequency shaft forms a substrate cooling gas feeding hole 21. The insulating material 46 penetrates from the base 41 to the insulating member 40. The high frequency supplying shaft 47 penetrates from the insulating member 40 to the holding member 2, one end (lower side in FIG.9) of the high frequency supplying shaft 47 being connected to a high voltage power source, which are not shown in the figure, for applying a high voltage to hold the substrate 1 to the dielectric material 18 by electrostatic adhesion and to a power source for applying a high frequency bias to the substrate 1. A substrate detecting sensor 24 for detecting the presence or absence of substrate by detecting the temperature of the substrate is installed in FIG.9. In this position, a substrate detector by detecting cooling gas pressure instead of detecting the substrate temperature may be also placed. In this case, the pressure sensor is placed at the top end of the pin in the substrate detecting sensor 24, an output signal wire from the pressure sensor being extracted through the inside of the pin to be connected to a signal processor. Since the pressure in the space around the top end of the pin in the substrate detecting sensor 24 is high when a substrate is present and is low when a substrate is absent, the signal processor detects the presence or absence of substrate by judging whether or not the pressure signal from the pressure sensor exceeds a value corresponding to a preset pressure. A susceptor 36 serving as a cover for the dielectric material 18 and the holding member 2 is placed in the outer peripheral portion of the substrate 1 to uniform the gas flow for substrate etching. The inner peripheral surface of the susceptor 36 is perpendicular to the back surface of the substrate 1. The susceptor 36 is formed of an electrically insulating material such as alumina, covering the outer surrounding of the holding member 2, the insulating member 40 and the base 41.

The substrate holding system shown in FIG.9 is used in, for example, a plasma environment as shown in FIG.10. FIG.11 is an enlarged cross-sectional view of the peripheral portion of the substrate 1. Although FIG.10 is a schematic view of a micro-wave plasma etching apparatus, explanation will be made below on a case where the substrate holding system according to the present invention is applied to an etching apparatus.

The vacuum chamber 27 is connected to another vacuum chamber to load and unload the substrate 1 from and into the atmospheric environment through a valve. The substrate 1 loaded into the vacuum chamber 27 through the substrate loading mechanism is transported at a transporting level indicated by a two-dot chain line in FIG.10. Therefore, the substrate holding system 9 is lowered to the transporting level. The substrate 1 is transported to and mounted on the dielectric material surface 18 by means of moving the pusher 19 upward and downward at this level. The coolant to control the temperature of the substrate 1 is introduced into the coolant flow passage 42 from the coolant supply portion 43 through a coolant temperature controller separately provided and is recirculated in the coolant flow passage to control the temperature of the holding member 2 and the dielectric material 18 at a given temperature. When the substrate 1 is mounted on the substrate holding system 9, the laser beam introduced from the substrate detecting sensor 24 is reflected on the back surface of the substrate, the reflected light being detected as a signal, mounting of the substrate 1 being confirmed. The temperature of the substrate is started to be detected using a substrate temperature detector (fluorescent thermometer), which is not shown in FIG.9, installed in the same manner as the substrate detecting sensor 24. When the etching gas is supplied and the microwave is introduced, discharging is started. In this state, direct current for electrostatic adhesion is supplied from the direct current power source 13, an electric circuit for electrostatic adhesion being formed through the plasma 16, the substrate 1 being attracted to the dielectric material 18. Then, when helium gas is supplied from the gas feeding hole 21, substrate temperature control through the helium gas is carried out. With this state, since the preparation for etching is completed, etching is started by setting the micro-wave at a given value and applying the high frequency voltage. After completion of the etching treatment, the high frequency voltage is stopped to supply. At this time, the plasma still remains. That is, the substrate is still kept to be attracted electrostatically. The etching gas is stopped to be supplied, non-etching gas such as argon gas instead of the etching gas being introduced depending on case-by-case to remove the charge accumulated during electrostatic adhering. In the meanwhile, the helium gas is stopped to be supplied, the force to lift up the substrate 1 from the back surface of the substrate 1 being no applied. After completion of discharging, the argon gas is stopped to be supplied, the direct current for electrostatic adhesion being stopped to be applied. After exhausting the etching gas and the gas for discharge and becoming a high vacuum state,

downward movement of the substrate holding system 9 and the process for unloading the substrate 1 are started. The unloading process is preformed in the inverse process of the loading process. A new substrate is loaded for the next etching. Then etching is carried out in the same manner as above.

Although the reaction products (gas) produced with etching gas and etching on the surface of the substrate is distributed in an approximately uniform density over the surface of the substrate 1, the etching characteristic in the peripheral portion may be different from that in the central portion since in the outer peripheral portion of the substrate the portion to produce the reaction products does not exist outside the substrate and the flow boundary of gas flow abruptly changes. Therefore, in the present invention, the susceptor 36 is placed approximately in the same level as the substrate 1 to prevent the gas flow from abrupt change. The flow of the etching gas and the reaction products is directed slightly upward due to existence of the surface of the susceptor 36, a stagnant effect of the etching gas and the reaction products takes place and causes a phenomena as if there is an etching reaction portion in the outer peripheral portion of the substrate. Therefore, etching is uniformly performed in the peripheral portion of the substrate.

In addition to the above, there is an effect that since the periphery of the substrate 1 is in a state of being contained in the susceptor 36 and the side wall 36A of the susceptor 36 restricts the substrate 1 to shift largely, it is possible to avoid the situation where the substrate cannot be transported and the vacuum of the etching chamber has to be broken even when the electrostatic adhering force is disappeared with some abnormal state and the substrate 1 is moved by the pressure of the helium gas supplied to the back surface of the substrate 1. At this time, the substrate 1 does not ride on the horizontal surface of the susceptor 36 even when the substrate 1 slides because the inner surface 36A of the susceptor 36 facing to the outer peripheral surface of the substrate 1 is nearly vertical. This case is different from a case where the surface of the susceptor 36 is taper-shaped.

Description will be made below on the gap between the back surface of the substrate 1 and the susceptor 16.

In the substrate etching surface side, the plasma 16 is generated and the etching gas and the reaction products are flowing. Therefore, when the gap between the back surface of the substrate 1 and the susceptor 16, the etching gas and the reaction products enter into the gap and are accumulated in the back surface of the substrate. They form foreign substances. This is not preferable because the product yield of etching process de-

creases. On the other hand, when the gap between them is decreased as small as possible, the etching gas and the reaction products are decreased to enter the gap and the foreign substances accumulated in the back surface of the substrate can be deceased. According to the result of another experiment, the effect described above has been effective when the gap is less than 0.3 mm.

The etching treatment is performed with applying the high frequency voltage to the substrate 1. At this time, there are some cases where an abnormal discharge takes place between the holding member 2 directly applied with the high frequency voltage and the base 41. When the abnormal discharge occurs, the high frequency voltage is not correctly applied to the substrate 1, the etching itself becomes abnormal. This is not limited to etching but can be said generally in the type of substrate treating apparatus in which plasma is generated using a high frequency voltage. In order to prevent these phenomena, in the substrate holding system according to the present invention, the base 41 being in a different electric potential from the high frequency voltage applied portion is specially isolated by inserting the insulating pipe 44. Thereby, the abnormal discharge can be prevented.

Description will be made on transportation of the substrate 1. Charge is accumulated on the substrate 1 while it is electrostatically adhering. The charge has capability of adhering the substrate 1 to the dielectric material 18, the substrate 1 is electrostatically attracted to the dielectric thin film even when the direct current power source 13 for electrostatic adhesion is switched off. Therefore, transportation of the substrate 1 has to be waiting until the accumulated charge is disappearing. There is an additional problem to judge whether the accumulated charge is present or absent. In order to solve this problem, the pusher 19 is made of a material having small conductivity such as silicon carbonate as shown in FIG.12. By doing so, the accumulated charge flows to a grounded line through the pusher 19 to disappear. Thereby, a trouble on transporting the substrate can be avoided and a reliable substrate transportation can be realized. The grounded circuit connected to the pusher 19 may be disconnected during generating the plasma. It is preferable to employ this manner when the grounded line and the high frequency applied portion are placed near each other and the abnormal discharge takes place.

Although the substrate 1 is transported with upward/downward movement of the pusher 19, an abnormal state occurs if the substrate is vibrated during transporting. Therefore, the pusher 19 has to move smoothly. In order to guide the pusher with certainty, in the present invention, the guide

45 is provided on the shaft 63. By doing this, the length of the pusher 19 does not become excessively long and high reliable transportation can be realized.

As described above, the elements of a high reliable substrate holding system have been clarified. Description will be made below on the solution of the problem in a case where the substrate transporting level is different from the level of substrate treating position (the substrate position corresponding to the position illustrated in FIG.10).

FIG.13 shows the comprehensive construction of a substrate holding system. The upper portion of the system is nearly the same as in FIG.9. The different portion from FIG.9 is that the outer side surface of the holding member 2 applied with the high frequency voltage is covered with an insulating member 40. By doing so, the distance between the high frequency voltage applied portion and the grounded portion becomes long and the preventive effect against the abnormal discharge can be improved.

In order to travel upward and downward between the substrate transporting position and the substrate etching position, a bellows 50 is provided between the shaft 63 of the substrate holding system, and the flange 49 in the present invention. The bellows 50 also serves as a vacuum seal between the atmosphere and the etching chamber and is extended with a guide for the shaft 63 and upward and downward drive mechanism installed in the atmospheric environment which are not shown in FIG.13. In the present invention, the bellows is placed between the shaft 63 and the flange 49 to minimize the diameter of the bellows 50. When the diameter of the bellows 50 is small, the force loaded on the substrate transporting mechanism is also small and consequently it is easily attained to make the upward and downward drive mechanism simple and highly accurate. It is needless to say that the foreign substances produced by abrasion in sliding portion are eliminated and the reliability against vacuum seal is improved comparing to a case of employing sliding portion using an elastomer seal.

Although by employing such a construction the substrate holding system is moved upward and downward, exposure of the bellows 50, the shaft 63, the pusher 19 to the plasma is not preferable in the point of problem of foreign substances formed by attached etching products or in point of plasma resistivity of the materials. Therefore, in the present invention, cylindrical covers 67A and 67B crossing with each other are provided in the base 41 and in the flange 49. The covers 67A, 67B cross with each other and have such dimensions that the crossing is kept even when the substrate holding system moves upward and downward. The both

covers 67A and 67B are kept in the grounded electric potential, the members inside the covers are always isolated from the plasma to be protected from contamination.

As described in the above embodiment, according to the present invention, a substrate holding system and a method of holding a substrate having less foreign substances and performing uniform etching can be attained.

It is understood that the present invention is not limited to the etching apparatus but widely applicable to the substrate treating apparatus and treating method requiring to hold substrate (treated object) with electrostatic adhesion.

In looking at FIG.9 or FIG.13 from the point to manufacture the above substrate holding system, it is difficult to manufacture the holding member 2 since it has the coolant flow passage. As a matter of course, it is possible to obtain a member having the same effect by means of manufacturing the holding member 2 by dividing into two parts through machining as shown in FIG.9, jointing each other, sealing the coolant using an elastomer seal. However, in this method, there arise such problems of trouble, complexity, decrease in reliability that extra jointing portions or extra volume is required since sealing surface 55 is required, a seal is required in each hole of the parts when a through hole (for example, the hole inserted with the insulating pipe 44 in FIG.9) is provided in the holding member 2 as shown in FIG.9.

Therefore, the present invention employs a manufacturing method where the holding member 2 is formed in a one-piece structure.

In the present invention, lost wax technique is employed as a method to solve this problem. FIG.14 shows this embodiment. First, a member having the same shape as the coolant flow passage 42 is fabricated using wax. Next, a mold having the same shape as the outer shape of the holding member 2 is prepared, the flow passage mold made of wax being placed inside the mold, and then casting is performed. After removing the wax, the holding member 2 is completed.

FIG.15 and Fig.16 show another embodiment according to the present invention. In this embodiment, a metallic member 52 machined the coolant flow passage 42 in advance and a holding member 53 are coupled with each other through a jointing material 54. When the holding member is made of aluminum or an aluminum alloy, an aluminum alloy having a low melting temperature (for example, a silicon contained aluminum alloy) is used for the jointing material 54. Then the members 52, 53 are heated up to approximately 600°C in a vacuum environment with pressing, the jointing material 54 having a low melting temperature being melted and reacting with the metallic members 52 and 53 to be

jointed to each other. Since the sealing surface 55 shown in FIG.16 can be certainly jointed by employing the diffusion welding method, the through hole 66 can be made without any special consideration. Since in the welding process many sets of members, not limited one set, can be welded at a time, there is no problem in cost performance by means of manufacturing a lot of the metallic members 52, 53 in advance and welding them at a time.

As described above, according to the present invention, since substrate holding by electrostatic adhesion can be certainly preformed without using member such as a weight on the substrate surface for preventing slide at substrate transporting or for preventing lift-up due to gas pressure on the back surface of the substrate, there is an effect that production of the foreign substances during substrate etching can be decreased and the production yield of the substrate can be expected to be improved. Further, since the operable period between cleaning services of the substrate etching apparatus for removing the foreign substances is lengthened, there is an effect that the operability of the apparatus can be expected to be improved. Furthermore, since the surface of the outer peripheral portion of the substrate is nearly at the same level as the surface of the substrate in order to make the gas flow in the surface of the substrate uniform, there is an effect that the substrate etching can be performed in excellently uniform over the surface. Still further, since no elastomer seal is required for coolant sealing in forming the substrate holding system, there is an effect that the substrate holding system can be easily manufactured.

#### Claims

1. A substrate holding system holding a treated substrate on a specimen table, cooling said treated substrate with the coolant gas between the specimen table and said treated substrate during treatment, which comprises:
  - a ring-shaped leakage-proof surface having smooth surface in the position corresponding to the periphery of said substrate;
  - a plurality of contact holding portions against said substrate on the specimen table between the corresponding position to the periphery of said substrate and the corresponding position to the center of said substrate; and
  - electrostatic traction means for fixing said substrate by contacting the back surface of said substrate to the ring-shaped leakage-proof surface and the contact holding portions.
2. A substrate holding system according to claim 1, wherein:
  - the contact holding portions have through

holes, pins for pushing up the substrate being placed in said holes.

3. A substrate holding system according to claim 1, wherein:
  - the contact holding portions on the specimen table are placed concentrically to the center of the specimen table in spaced relationship with each other.
4. A substrate holding system according to claim 1, wherein:
  - the contact holding portions on the specimen table are composed of a plurality of island-shaped protruded portions, said island-shaped protruded portions being placed concentrically to the center of said specimen table in double-array in spaced relationship with each other.
5. A substrate holding system in a plasma treatment apparatus having a vacuum treating chamber, gas introducing means and a specimen table mounting a substrate in the vacuum treating chamber where the substrate is held to the specimen table with electrostatic adhesion force and the temperature of the substrate is controlled by introducing a cooling gas between the substrate and the specimen table, said specimen table comprises:
  - a ring-shaped protruded portion having smooth surface in the position corresponding to the periphery of the substrate;
  - a plurality of contact holding portions against said substrate on the specimen table between the corresponding position to the periphery of said substrate and the corresponding position to the center of said substrate; and
  - said substrate holding system further comprises:
    - electrostatic traction means for fixing said substrate by contacting the back surface of said substrate to the ring-shaped protruded portion and the contact holding portions.
6. The substrate holding system according to claim 1, wherein:
  - the height of the ring-shaped leakage-proof surface and the contact holding portions is 15 $\mu$ m ~ 200 $\mu$ m.
7. The substrate holding system according to claim 1, wherein:
  - the contact area of the ring-shaped leakage-proof surface and the contact holding portions to the substrate is less than one half of the area of the substrate.

8. A substrate holding system according to claim 1, which is constructed such that the excess portion of the cooling gas flowing through the holes penetrating the contact holding portions flows toward the specimen table opposite to the substrate to carry foreign substances produced in the holes. 5
9. A substrate holding system according to claim 1, which comprises a cover on the specimen table in the opposite side of the substrate, the pressure inside said cover being kept higher than that in the treatment chamber during treating by means of introducing the excess gas of the cooling gas inside the cover to prevent the products of reaction in the treating chamber from entering into the inside of the cover. 10 15
10. A substrate holding system according to claim 8, which comprises a region on said holding member contacting to the back surface of said substrate around a transfer member of said substrate provided in the inner side of the gas leakage-proof surface in said holding member to prevent the gas for coolant from massively leaking through the installation portion of the transfer member. 20 25
11. A substrate holding system according to claim 8, wherein the gas leakage-proof surface provided around said transfer member is an adhering surface utilizing electrostatic force. 30
12. A substrate holding system according to claim 8, which comprises a region on said holding member contacting to the back surface of said substrate around said temperature measurement member to prevent the gas for coolant from leaking through the installation portion of said temperature measurement member. 35 40
13. A substrate holding system in a plasma treatment apparatus having a vacuum treating chamber, gas introducing means and means for mounting a substrate in the vacuum treating chamber where the mounting table for mounting the substrate holds said substrate with electrostatic adhesion force and the temperature of said substrate is controlled by introducing a cooling gas between said substrate and the mounting table, wherein:  
the contact area of said substrate and the mounting table by electrostatic adherence is less than one half of the area of said substrate, the mounting table having a nearly one-round contact portion between the periphery of said substrate and the center of said substrate other than the contact portion of the periphery of said substrate, said mounting table except its contact portions having a gap to the substrate to accelerate the diffusion of the cooling gas when introduced, a passage allowing the cooling gas to flow out to the back of the mounting table other than the leakage through the peripheral portion of said substrate. 45
14. A substrate holding system according to claim 13, wherein a hole allowing the cooling gas to flow out to the back of the mounting table is provided on a cover having a conductance against the vacuum treating chamber. 50
15. A method of holding a substrate where a holding member having a temperature measuring member has a control function for the temperature of a substrate, the substrate being mounted on and fixed to said holding member having temperature control function, then a gas being supplied between said holding member and the back surface of said substrate from a gas supplying portion provided on the holding member to cool said substrate using said gas as a coolant, which comprises:  
contacting the peripheral portion of said substrate to a ring-shaped gas leakage-proof surface provided on the periphery of said holding member, adhering the peripheral portion of said substrate to said gas leakage-proof surface by electrostatic force to prevent the gas supplied to the back of said substrate from leakage. 55
16. A method of holding a substrate according to claim 15, wherein the substrate is held by a plurality of substrate supporting portions provided on the holding member in the inner side of the gas leakage-proof surface to prevent said substrate from deformation.
17. A method of holding a substrate according to claim 15, wherein the gas leakage-proof surface is provided around the temperature measurement member, said gas leakage-proof surface serving as an adhering surface utilizing electrostatic force.
18. A method of holding a substrate according to claim 15, wherein the substrate holding member also serves as a temperature measurement member.
19. A substrate holding system for holding a substrate in a substrate etching apparatus, wherein said substrate holding system holds said substrate by using electrostatic force, a susceptor



made of an electrical insulating member having a top surface approximately in the same level as the treated surface of said substrate and having a inner side surface in outer positioned relationship with the surface of said substrate being constructed in the periphery of said substrate, the inner side surface of said susceptor facing to the periphery of said substrate being in nearly parallel relationship with the normal direction of the treated surface of said substrate.

20. A substrate holding system according to claim 19, wherein a dielectric thin film made of a brittle material for holding said substrate with electrostatic force is formed on one surface of a holding member having a flow passage for circulating a coolant to control the temperature of said substrate, an electrically insulating material member being placed on and contacted to the other surface of said holding member, an electrically high conductive material member grounded to a standard electric potential being placed on the other surface of said holding member, three kinds of said members being overlaid and fixed to each other in order of the holding member having the dielectric thin film, the electrically insulating material member and the standard electrical potential member, a flow passage penetrating from said standard electric potential member to the coolant flow passage in said holding member for supplying and discharging coolant having the side surface formed of a electrically insulating member being provided, tubes having the side surface made of electrically insulating material forming at least three through holes penetrating said three kind of members into which movable members linked to a substrate transporting mechanism are inserted, a pipe-shaped member made of an electrically high conductive material being attached to said standard electrical potential member to support said three kinds of members, a small diameter pipe-shaped member made of an electrically high conductive material being inserted into the inside of said pipe-shaped member through an electrically insulating material, said small diameter pipe-shaped member being connected to said holding member penetrating through said standard electric potential member and said electrically insulating material member, an electric potential for generating an electrostatic force to hold said substrate and an high frequency voltage required for etching said substrate being applied through said small diameter pipe-shaped member, a tube having the side surface made of an electrically insulating

material forming a through hole being provided in said holding member and said dielectric thin film in such a feature that gas can be supplied from the inside hole of said small diameter pipe-shaped member to the gap between the back surface of said substrate and the surface of said dielectric thin film.

21. A substrate holding system according to claim 20, wherein the movable member linked to said substrate transporting mechanism is made of an electrically conductive material.
22. A substrate holding system according to any one of claim 20 to claim 21, wherein said dielectric thin film and said holding member are covered with a member made of an electrically insulating material in such a feature that said dielectric thin film and said holding member are not seen in the peripheral portion of said substrate when said substrate is held on the surface of said dielectric thin film.
23. A substrate holding system according to any one of claim 20 to claim 22, wherein the surrounding of said holding member is covered with an electrically insulating material, the further outer surrounding being covered with an electrically high conductive member electrically connected to said standard electric potential member, the furthermore outer surrounding being covered with an electrically insulating material cover member.
24. A substrate holding system according to any one of claim 20 to claim 23, wherein a guide for moving the movable member inserted into the through hole for transporting said substrate is provided outside said pipe-shaped member.
25. A substrate holding system according to any one of claim 19 to claim 24, wherein the substrate holding system is fixed to a flange in the substrate etching apparatus by using an extendable sealing member provided between said pipe-shaped member and said flange, the movement of said substrate holding system to place the substrate in a position suitable for treating said substrate being preformed by means of extending said sealing member.
26. A substrate holding system according to any one of claim 19 to claim 25, wherein a nearly cylinder-shaped cover is provided in the outer portion of said standard electric potential member, a nearly cylinder-shaped member having a different diameter from said cover being fixed to said flange, the inside of said cylinder-

shaped member being covered with overlap of said cylinder-shaped member when said substrate holding system moves up and down.

27. A substrate holding system according to any one of claim 19 to claim 26, wherein a tube having the side surface made of an electrically insulating material is provided to form a through hole in said three kinds of member, a detector for measuring the temperature of a substrate held on said dielectric thin film being placed in said through hole. 5 10
28. A substrate holding system according to any one of claim 19 to claim 27, wherein a tube having the side surface made of an electrically insulating material is provided to form a through hole in said three kinds of member, a detector for detecting the presence or absence of a substrate held on said dielectric thin film being placed in said through hole. 15 20
29. A substrate holding system according to claim 28, wherein said detector for detecting the presence or absence of a substrate is an optical fiber, the detection of the presence or absence of a substrate being judged by whether the light introduced through the fiber is reflected by the back surface of said substrate. 25 30
30. A substrate holding system according to claim 28, wherein the detection of the presence or absence of said substrate is performed using the signal from a detector for detecting the temperature of the substrate. 35
31. A substrate holding system according to claim 28, wherein the detection of the presence or absence of said substrate is performed using the signal from a detector for detecting the gas pressure for cooling the substrate. 40
32. A substrate holding system according to any one of claim 19 to claim 27, wherein diffusion welding is used to form the coolant flow passage for control the temperature of said substrate in said holding member. 45
33. A substrate holding system according to any one of claim 19 to claim 27, wherein soldering is used to form the coolant flow passage for control the temperature of said substrate in said holding member. 50
34. A substrate holding system according to any one of claim 19 to claim 27, wherein casting is used to form the coolant flow passage for control the temperature of said substrate in 55

said holding member.

35. A substrate holding system according to any one of claim 19 to claim 27, wherein the gap between the cover member covering said electric thin film and said holding member and the portion facing to the back surface of the periphery of said substrate is less than 0.3 mm.

FIG. 1

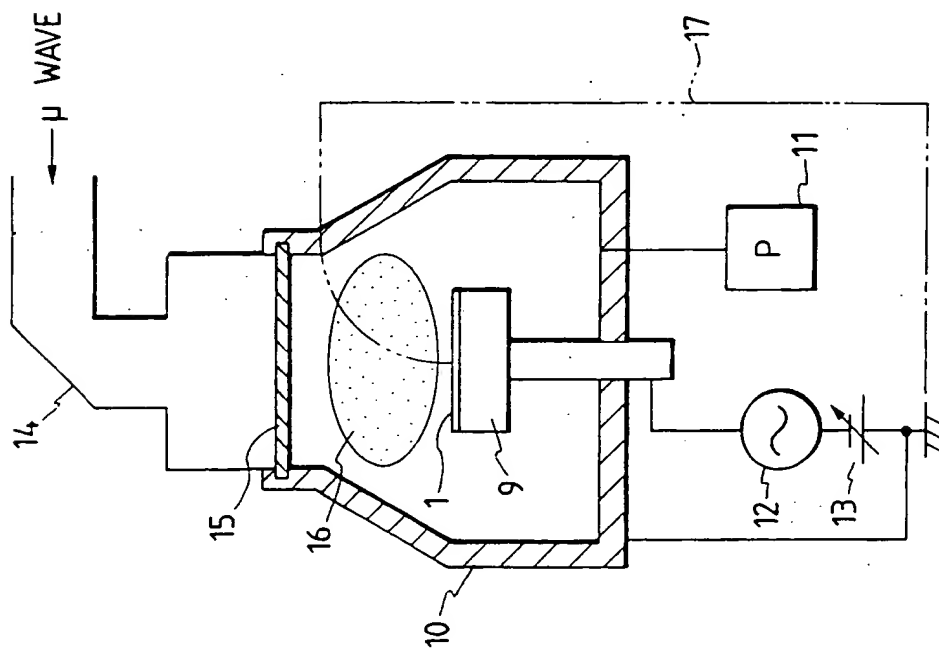


FIG. 2

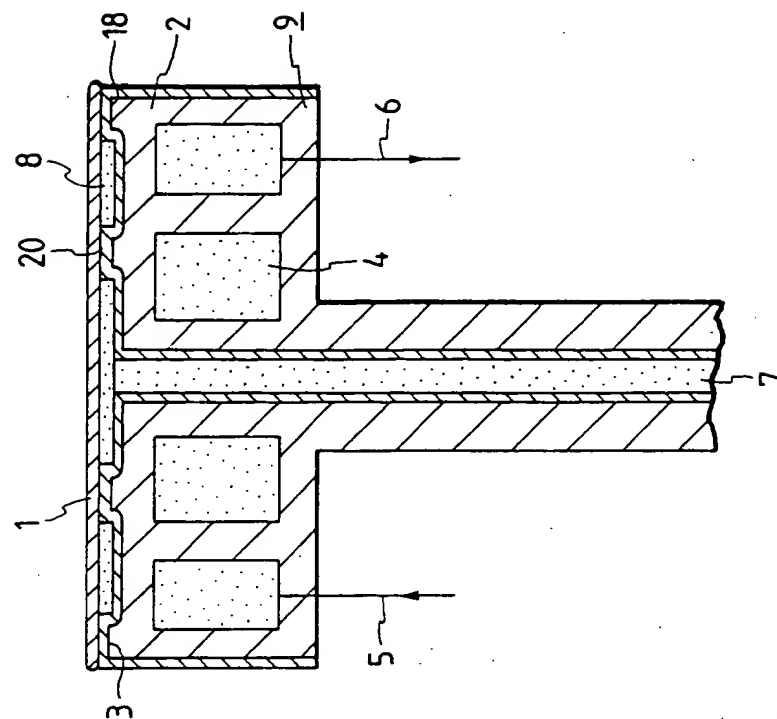


FIG. 3

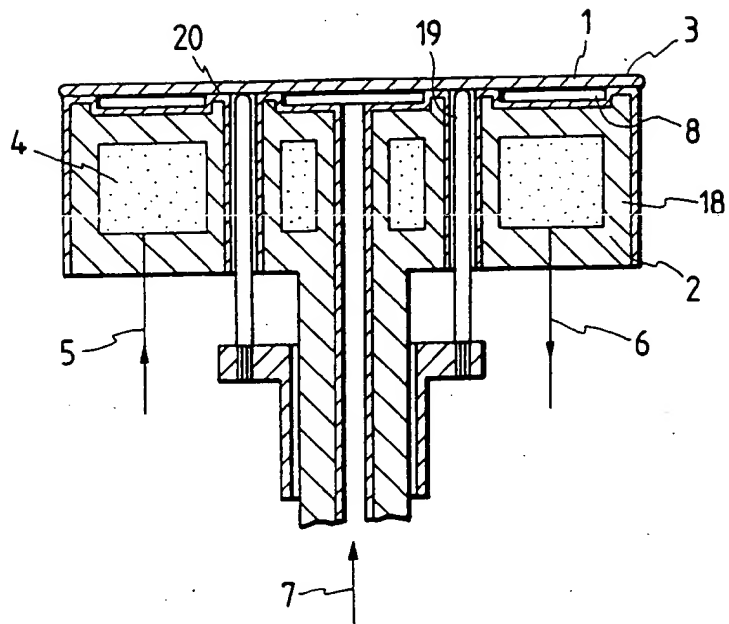


FIG. 4

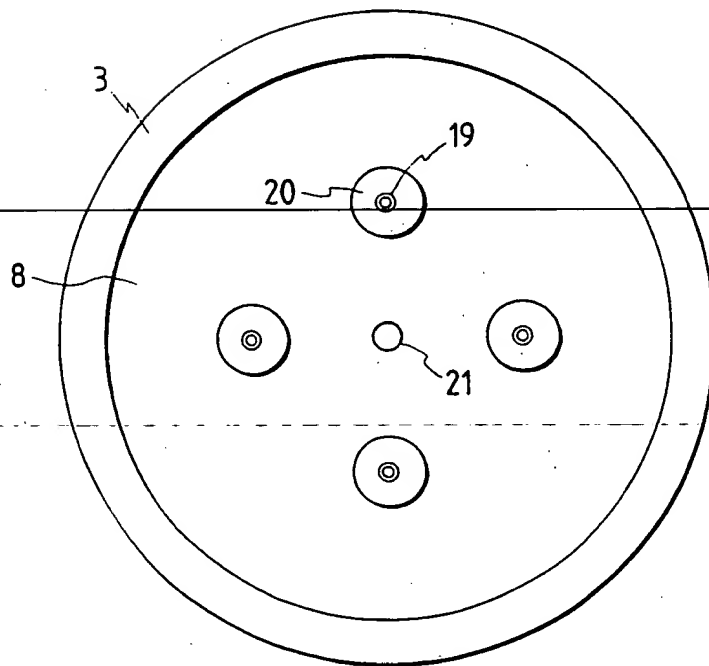


FIG. 5

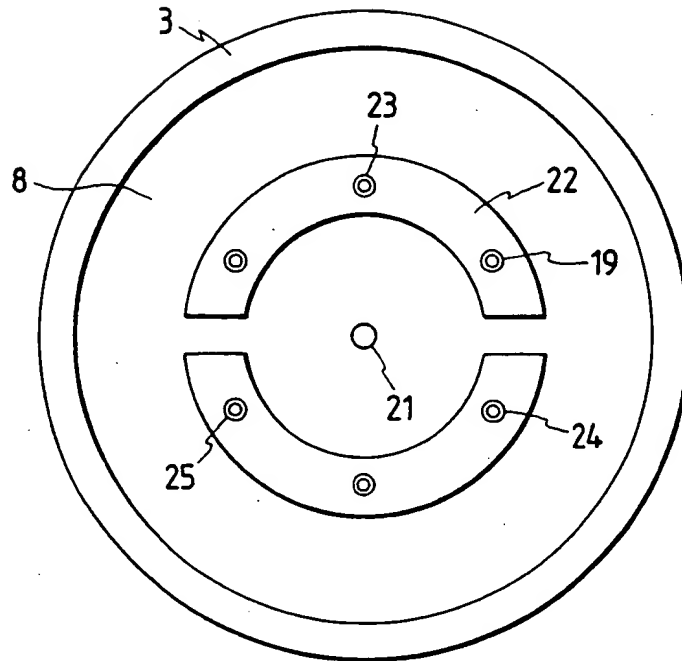


FIG. 6

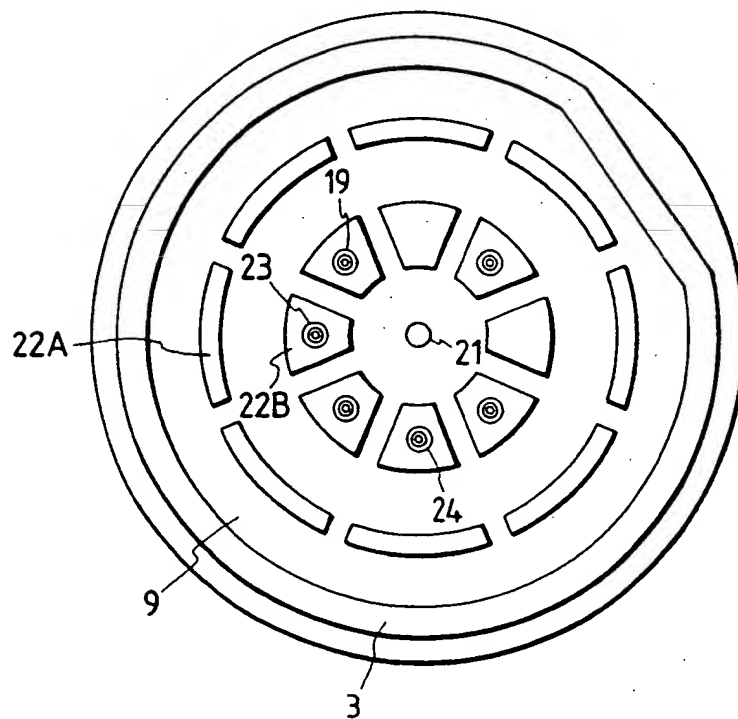


FIG. 7

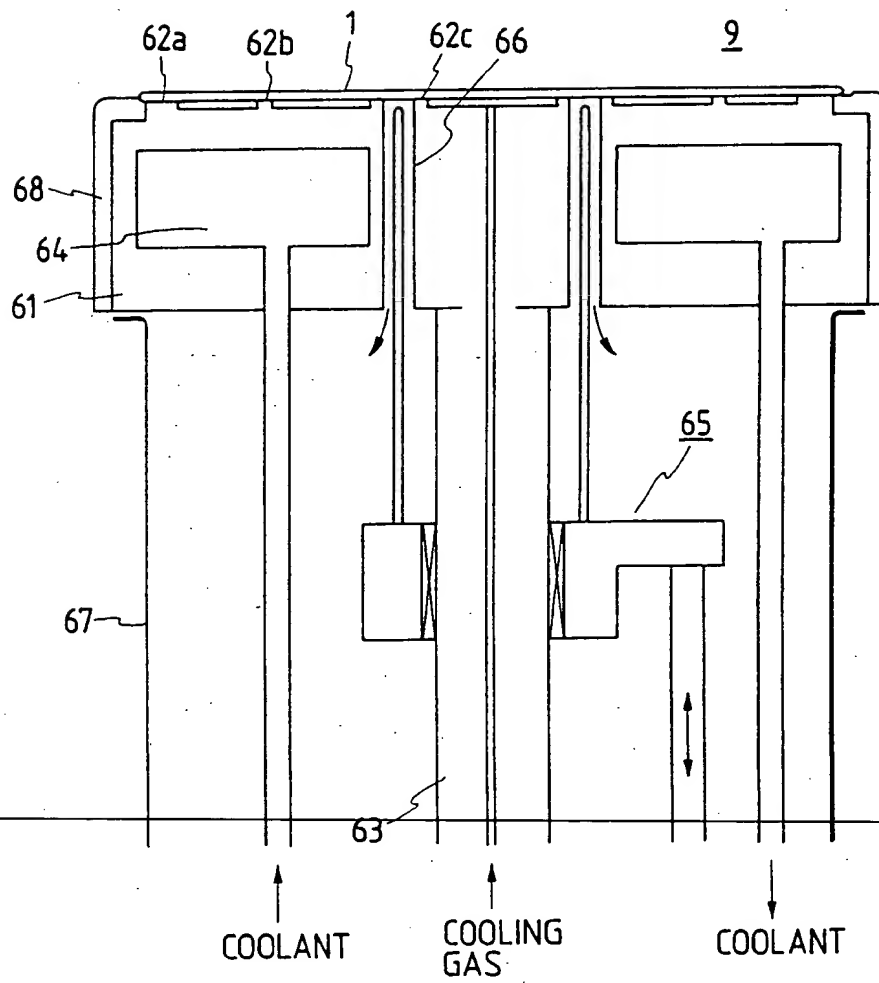


FIG. 8

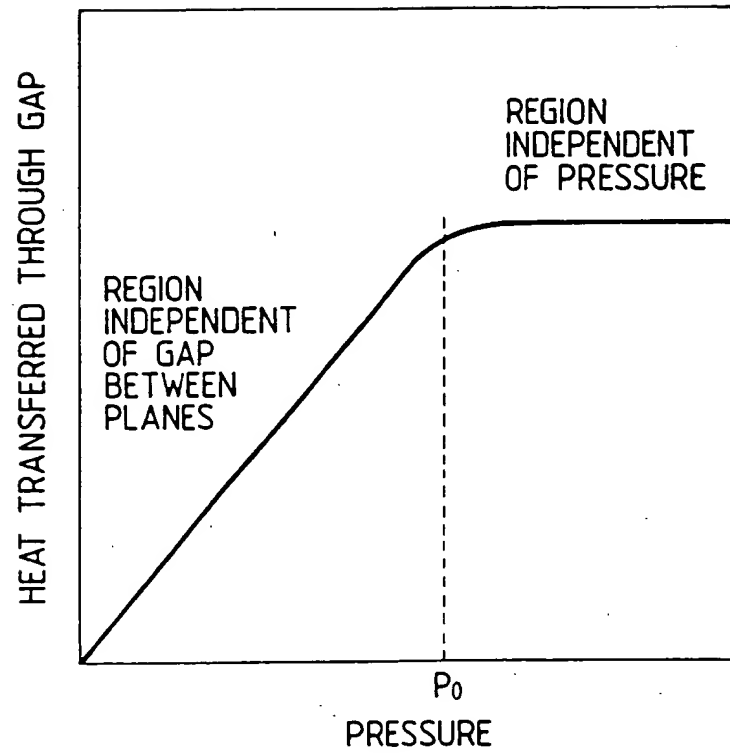


FIG. 9

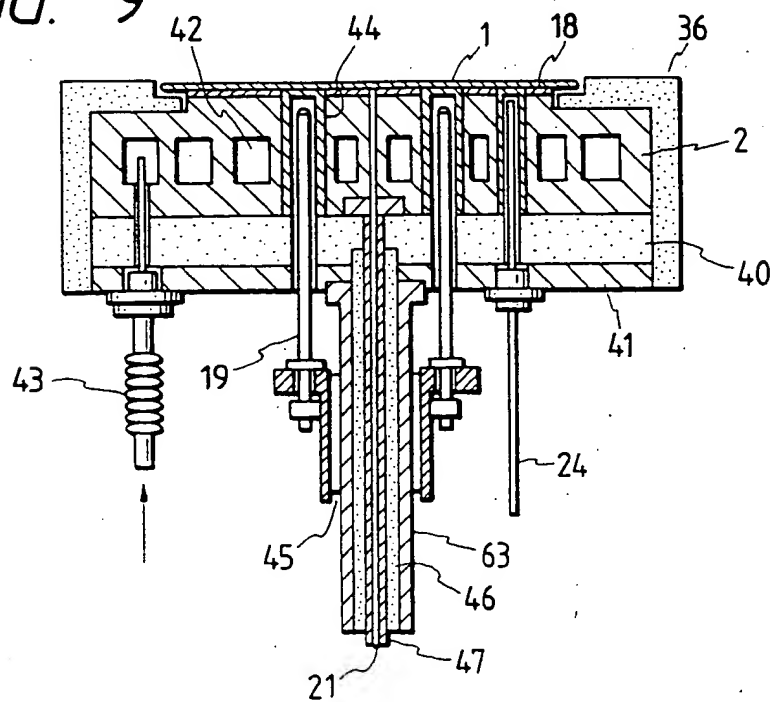




FIG. 10

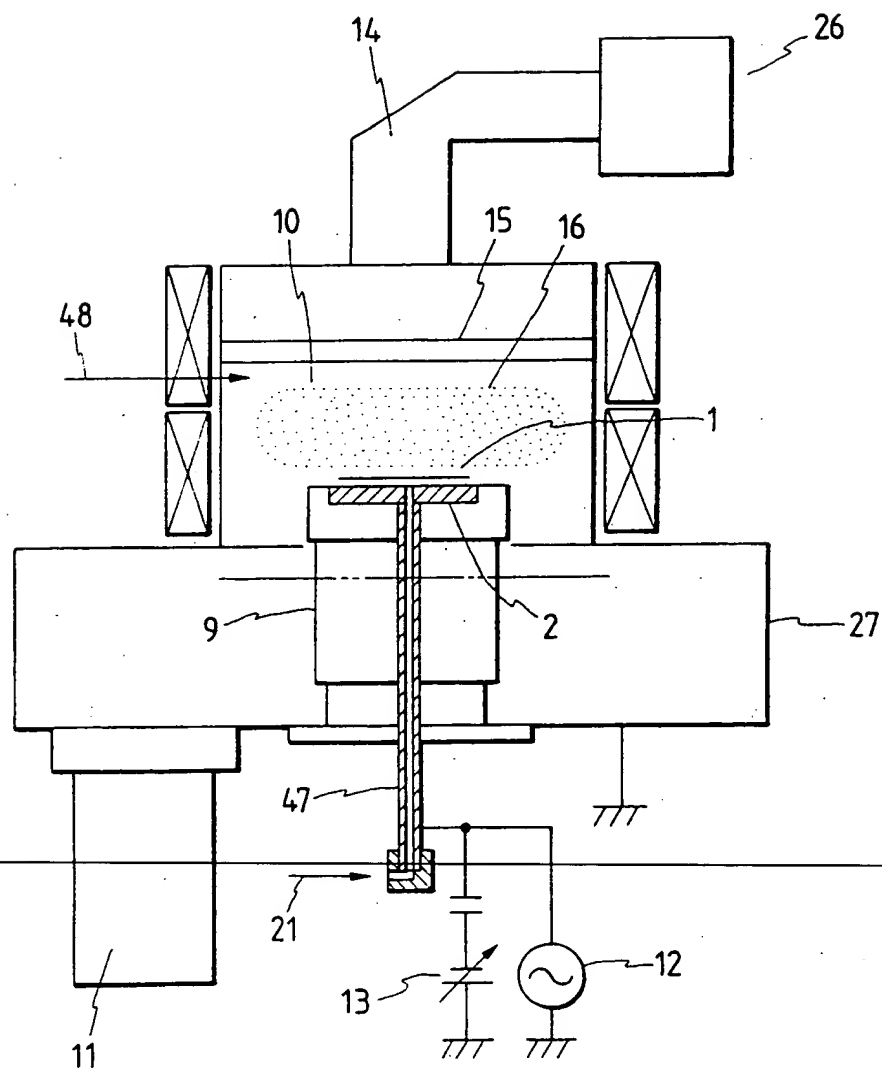


FIG. 11

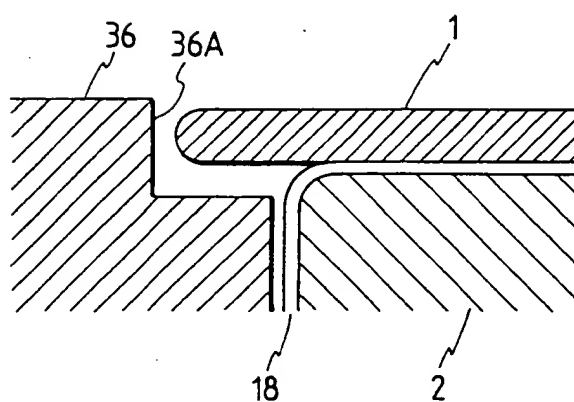


FIG. 12

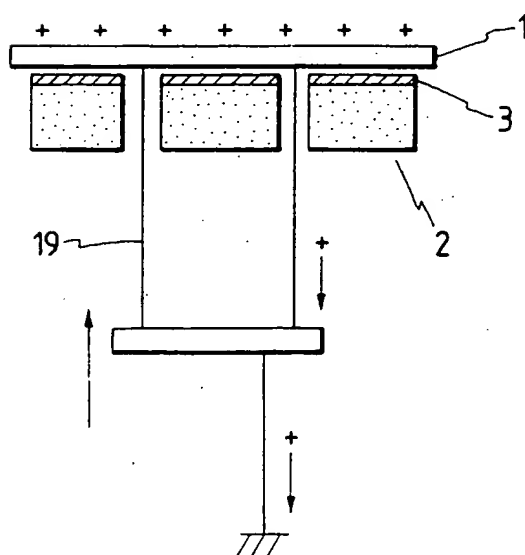


FIG. 13

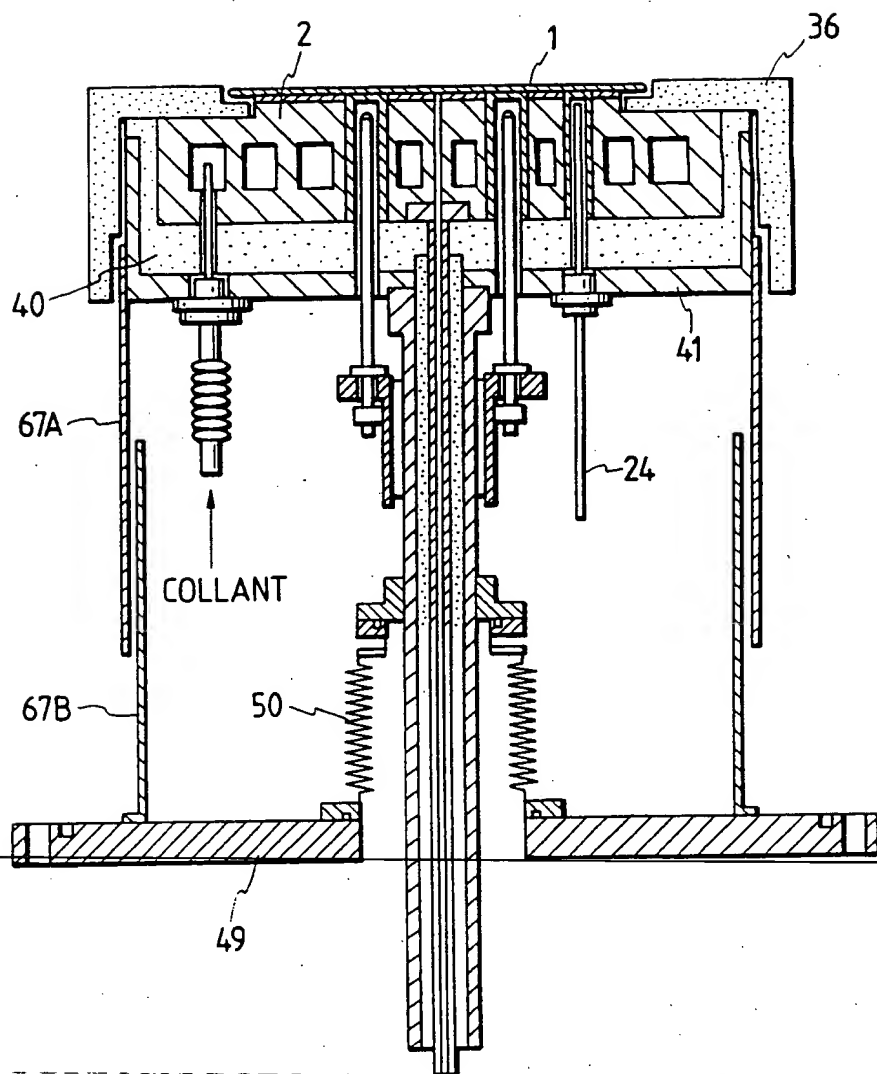


FIG. 14

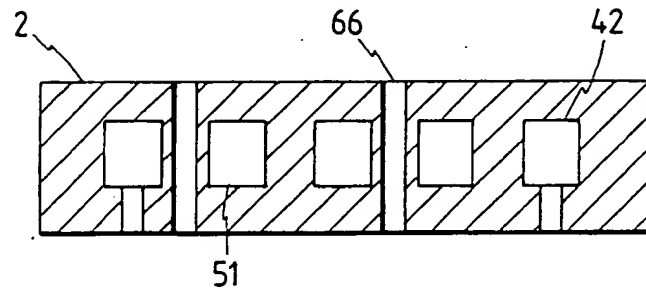


FIG. 15

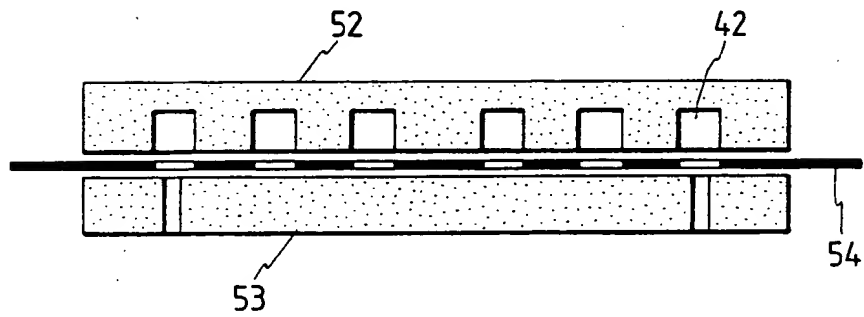
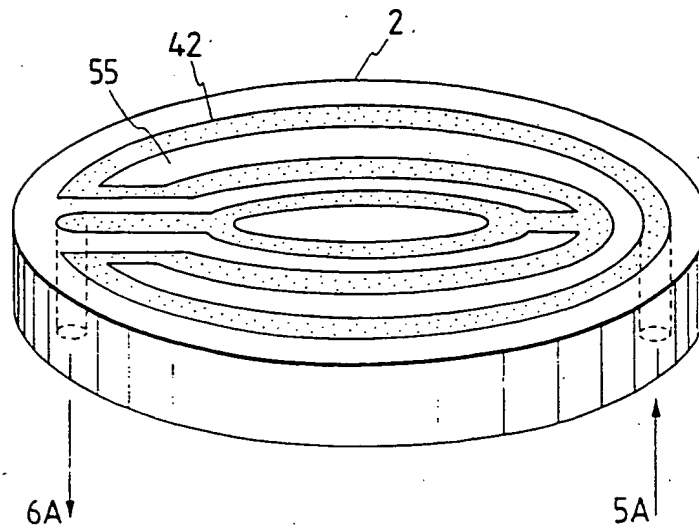


FIG. 16





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Publication number:

**0 644 578 A3**

(12)

## EUROPEAN PATENT APPLICATION

(21) Application number: 94113803.4

(51) Int. Cl.<sup>6</sup>: H01L 21/00

(22) Date of filing: 02.09.94

(30) Priority: 16.09.93 JP 230187/93  
18.03.94 JP 48286/94

(43) Date of publication of application:  
22.03.95 Bulletin 95/12

(84) Designated Contracting States:  
DE GB IT

(88) Date of deferred publication of the search report:  
19.04.95 Bulletin 95/16

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(54) Method of holding substrate and substrate holding system.

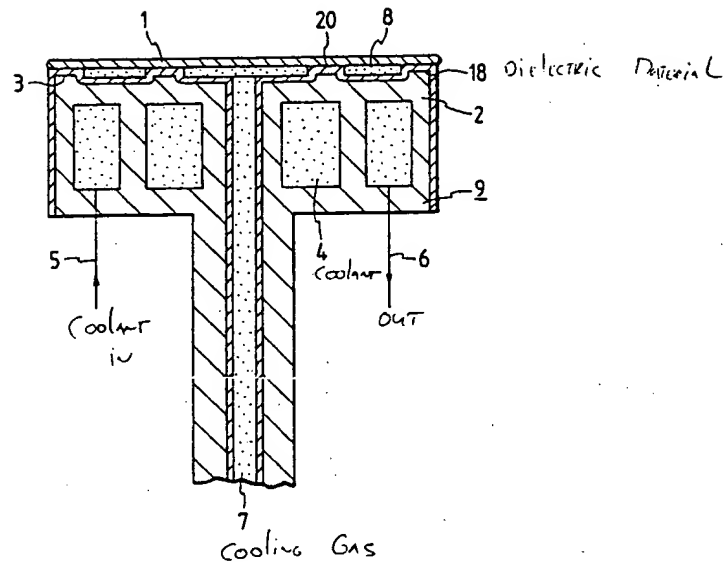
(57) Present invention provides a method of holding substrate and a substrate holding system where the amount of foreign substances on the back surface can be decreased, and a little amount of foreign substances may be transferred from a mounting table to a substrate. The substrate holding system comprises a ring-shaped leakage-proof surface having smooth surface on the specimen table corresponding to the periphery of the substrate, a plurality of contact holding portions against the substrate on the specimen table between the corresponding position to the periphery of the substrate and the cor-

responding position to the center of the substrate, and electrostatic traction means for fixing the substrate by contacting the back surface of the substrate to the ring-shaped leakage-proof surface and the contact holding portions. The substrate contacts to the cooling surface at the ring-shaped leakage-proof surface and the contact holding portion placed on a position inside the ring-shaped leakage-proof surface. The back surface of the substrate and the cooling surface do not contact to each other in the large portion of the remaining area.

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FIG. 2





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# EUROPEAN SEARCH REPORT

Application Number  
EP 94 11 3803

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X A	US-A-5 213 349 (ELLIOTT) * the whole document * ---	1-4 5,15-17	H01L21/00
X	EP-A-0 357 424 (CANON KABUSHIKI KAISHA)  * column 3, line 5 - column 4, line 64; figures 2A-3B * ---	1,3,4, 15-17	
A	EP-A-0 452 222 (COMMISSARIAT A L' ENERGIE ATOMIQUE) * column 3, line 15 - column 4, line 9; figures 1,2 * ---	1,5,15, 16	
A	PATENT ABSTRACTS OF JAPAN vol. 17, no. 672 (E-1474) 10 December 1993 & JP-A-05 226 292 (TOKYO ELECTRON YAMANASHI KK) 3 September 1993 * abstract * & US-A-5 310 453 (FUKASAWA) -----	1,2,5,13	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01L
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		25 November 1994	BOLDER G.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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### CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- ☐ All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.
- ☐ Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claims:
- ☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

### LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions.

namely:

See sheet -B-

- ☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- ☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:
- ☒ None of the further search fees has been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims: 1-18

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EP 94 11 3803 -B-

#### LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims 1-18: Substrate holding system, substrate cooled by gas and attracted by electrostatic force
2. Claims 19-35: Substrate holding system, substrate being etched and attracted by electrostatic force

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